RADAR Basics

By Cherub Log

For most of those reading these Radar and related articles, the concept of the technology will be familiar. For those however who have had little or no exposure to Radar, this chapter will provide some of the basics.

A simple analogy is to imagine you are standing at Echo Point in Sydney's Blue Mountains, and you shout "Hello". Within a second or so your ear detects an audible echo. Now as the speed of sound is known, and if you can accurately time the interval between your shout and the echo, the distance to the obstruction which caused the echo, eg mountain rock face, can be simply calculated. The formula is d distance = v velocity (of sound waves) multipled by t/2 (half the elapsed time). The half is to allow for the sound to travel in both directions.

For Radar, instead of sound waves we have electomagnetic waves which have a velocity of 300 million metres per second. To measure time, there are a number of different electronic clocks which can be used and which can be highly accurate. As well, to do the arithmetic of t (time) multiplied by v (velocity) = d (distance), there are more electronic calculators. To illustrate, if a pulse of electromagnetic transmision is sent and the returned echo comes in 50 microseconds, the target is distant 7.5 kilometres as follows: d = v times t. Thus d = 3 x 10 to the power of 8, times 50 times 10 to the power of minus 6 =15,000 metres = 15Km. Thus the target is 7.5 Km distant

There are variations on this principle. One such is known as the Doppler Effect. Here it is not the time difference which is measured but the frequency difference. To explain Doppler effect, imagine you are standing on a railway station and you hear an approaching train, which in this case is an express train to pass straight through your station. As the train approaches, not only does the sound of it change in volume, but also the frequency or pitch of the sound changes slightly. In fact it increases as the train approaches, then decreases as the train leaves your station. This effect is caused by the velocity of the train's sound waves being increased by the velocity of the train as it approaches, and decreased similarly as the train roars off into the distance. So it is with electromagnetic waves in that there is a small frequency shift when there is a radial difference in range occurring between the Radar set and the target. As an example, at an operating frequency of 10 GHz (10,000 MHz or 3 centimetre wavelength) a radial velocity of 1 nautical mile (1.883 kilometres) per hour provides a Doppler frequency shift of 34 Hz. It should be noted however that the Doppler effect occurs only when there is a radial difference between the Radar set and the target. If both the Radar set and the target are travelling in a straight line at the same speed, Doppler effect will be zero because the relative distance separation remains constant, and thus no frequency shift. As well, if the target is moving in a circular path of constant radius about the
Radar set, again there will be no frequency change, thus no Doppler effect.

In 1937 when the Home Chain system was introduced, there was one Radar function, that of early warning. In the 21st century there are many functions. Some are Control (Air Traffic Control), Navigation (Terrain Following Radar), Dock (Capsule Docking Radar), Land (Microwave Landing System), Map (Side-looking Radar)

All Radar systems need to obtain certain information. Typical are range, velocity and acceleration, azimuth direction, elevation angle, target signature.

In the immediate pre WW2 days, designs of the various thermionic valves limited the frequency at which a Radar system could operate. Typically this was in the high frequency range up to 50 Megacycles*, a wavelength of 6 metres. With the developments of the magnetron and klystron, frequencies up to 10,000 Megacycles , wavelength 3 centimetre, could be achieved. In the 21st century the Radar bands assigned by the International Telecommunications Union are as follows:

BAND	FREQUENCIES

VHF	138 – 144 MHz
	216 – 225 MHz
UHF	420 – 450 MHz
	890 – 942 MHz
L	1215 – 1400 MHz
S	2300 – 2500 MHz
	2700 – 3700 MHz
C	5250 – 5925 MHz
X	8500 – 10,680 MHz
Ku	14.4 – 14.0 GHz
	15.7 – 17.7 GHz
K	24.05 – 24.25 GHz
Ka	33.4 – 36.0 GHz

* The term cycles has been replaced in recent years by the term Hertz

The relationship between frequency , wavelength and velocity is constant where wavelength equals velocity divided by frequency. As an example, a wavelength of 30 centimetres will be derived from a velocity of 3 X 10 to the power of 8 divided by 1,000 MHz (1,000 X 10 to the power of 6.)

Again for the benefit of those not familiar with Radar, following are brief explanations of some of the words and terms used in these articles:

75 ohm coax Coax is the coaxial cable used to carry electromagnetic signals. The 75 ohm does not refer to standard direct current (DC) resistance. Typically the DC resistance in coax is zero. Here it is the impedance to alternating current signals. For maximum signal transference, the coax should exhibit the same impedance as that of the device to which it is attached, eg the receiving aerial, or the video amplifier etc.

A scan This is a single line horizontal trace on a cathode ray oscilloscope (CRO). At the left hand end, the large vertical pulse indicates the initial transmission signal. To the right along the trace, a returned echo is shown as another smaller vertical pulse.

A scope See “A” scan

Bedstead array Using a bit of imagination, this antenna looks very much like an old fashioned wire spring bed base, mounted on its long edge on the ship’s mast.

Bowden cable This is a strong flexible and usually lengthy cable used to transfer physical movement. For example, an operator in a Radar office turning a wheel that is connected by bowden cable to the antenna on the mast head, can cause the antenna to move in the direction and by the amount that the operator desires

Double cheese This type of antenna looked like two half circular cheeses, but much larger.

Klystron Using the superhetrodyne principle of radio reception (see explanation of this), the klystron was used initally as a local oscillator. As the technology developed, more powerful klystrons were developed and used as transmitters.

Lantern Imagine an old fashioned cylindrically shaped lantern, but much larger. In this on the mast would be housed the Radar antenna, and in some cases much of the transmitting and receiving equipment.

M type transmission A 24 volt DC hand driven generator, when electrically connected to a similarly constructed motor, can cause the motor to turn in sympathy as the generator is turned. If the motor is mechanically connected to a Radar antenna, a Radar operator in the Radar shack could remotely turn the Radar antenna on the ship’s mast.

Magnetron This was one of the main transmitters. It could produce electromagnetic signals at frequencies between 10,000 and 3,000 MHz, for pulse durations of less than 1 microsecond, at pulse repetition rates of hundreds per second and with peak power outputs of hundreds of watts.

Micro dog This was a high power transmitting triode, NT98

Micro pup This was a low powered transmitting triode, NT99

Modulator This is simply the device which regulates the frequency, and sometimes the duration of the Radar transmission pulses

Motor alternator Standard electrical power supplies in HM ships during WW2, and for some time after, was 220 volts DC. All electronic equipment operated on alternating current (AC) at different voltages. A motor alternator was a DC electric motor mechanically connected to an alternator. Thus as power was applied to the DC motor, AC was delivered from the alternator.

PPI Plan Position Indicator was a circular Radar display (a modified cathode ray oscilloscope), with the source being at the centre of the circle. As the transmitter pulsed, a representative trace was projected on the screen emanating from the centre and extending to the periphery of the screen. A returned echo would be seen as a bright spot on the trace. As the antenna rotated, the PPI trace would rotate in synchronism. Thus not only the range of the target could be seen on the calibrated scale, but also its orientation in relation to ships head, of if desired, in relation to a fixed bearing such as magnetic or true north. Variations of this allowed the presentation of slant range of aircraft echos. Thus range, azimuth and altitude of aircraft could be quickly determined.

PRF Simply, pulse repetition frequency, or the number of transmitted pulses each second. These varied between Radars, but a PRF of 500 was typical.

Rx Shorthand for receiver

Sector sweep Refer to PPI. Instead of a 360 degree continuous rotation, some models were designed to allow backwards and forwards sweeps of a selected sector, eg 20 degrees both sides of ship's head

Spark gap This was one form of modulating transmissions. (See Jake Kerr's story of A272)

Superhetrodyne principle Amplification of electromagnetic signals is made more reliable by mixing the desired signal with one at a slightly different frequency, and by selecting the resultant difference. Thus the reflected echo signal of a magnetron transmission at 10,000 MHz, could be mixed with a klystron generated local signal of, say, 10,009 MHz. There would be 4 resultant signals ie the original two, the sum (20,009 MHz) and the difference (9 MHz). Selection of the 9 MHz for further amplification would produce the best frequency to be used to create the displayed echo signal.

Thermionic valve This was the forerunner to the transistor which in turn was the forerunner to integrated circuits, used in the millions today in radios, TV, mobile telephones etc. In appearance, generally it looked like a normal electric light globe. The principle of operation was that a constant stream of electrons would be emitted from the heated cathode, and the quantity of these electrons would be varied by an electric signal applied to the grid, placed physically between the cathode and the anode, which because it had a high tension voltage applied, would attract the cathode emitted electrons. In this process, the amplitude of the signal coming in to the grid would appear greatly magnified when seen at the anode. There were many variations of this device. The distance which the electrons had to travel from cathode to anode was a factor which determined the frequency limits of the valve in question.

Thiratron This was a high power mercury vapour triode used as a pulse modulator for transmitters

Tx Shorthand for transmitter.

Variac A mechanical hand operated device for varying the voltage output of an alternator

Wave guide At lower frequencies, radio signals can be successfully carried over copper wire. At higher frequencies this does not work at all well. Waveguide is rectangular section metal tubing, sometimes gold plated on the inner surfaces. UHF and higher radio signals carry much more effectively along the inside of waveguide material. The length of the waveguide can be many metres without significant loss of performance. The dimensions of the cross section must relate to the frequency of the transmitted signal. A 3 cm transmission uses 3 cm cross section waveguide for example.

Wave guide horn See wave guide. At the antenna, the transmission signal leaves the waveguide and is directed to the antenna via an aperture or horn. For example, if the antenna is a parabolic reflector, the horn is located at the focal point, which may be up to 50 centimetres from the nearest point of surface of the reflector.

Yagi array An antenna array named after its Japanese inventor. Essentially it is a straight rod pointing away from the ship's mast in horizontal orientation. The active element which is connected to the transmitter is a transverse element, generally about 30% along the rod from the mast end. Nearest the mast are 2 or 3 transverse elements, slightly longer than the active element. These are the reflectors. Then progressively located away from the active element in a forward direction, each slightly shorter than its predecessor and the active element are the directors. The net result is a highlydirectional antenna. Yagi antennas are common in domestic free to air televsion set ups.